Preparing Students for Professional Practice through Industry-based Projects

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ABSTRACT

The educational value of student projects involving industry has been well recognised at the University of Auckland for a considerable time. Technology management and design projects drawn from industry are organised as capstone experiences in the final year of the undergraduate curriculum, and provide students with a range of open-ended, complex, multi-disciplinary problems and expose them to team-based problem solving in a realistic business, societal, and environmental context.

In line with CDIO principles these projects are designed to help students understand market and business needs, appreciate a range of ethical, social, environmental and legal requirements, and develop a systems perspective of professional engineering work. Projects are organised in such a way that they encourage students to set realistic goals, apply sound project and team management procedures and create innovative solution concepts on the basis of their fundamental technical engineering knowledge.

These projects provide significant educational benefits which are achieved through a combination of careful project selection and organisation, comprehensive team facilitation and management, and the application of appropriate assessment procedures. In this paper the effectiveness of various tools and methods applied in the course are discussed. Issues covered include the identification of the individual student knowledge gained through team-based project courses, the application of novel assessment tools to encourage deep and reflective learning, as well as the relationship between achieving the stated project objectives and the course learning outcomes.

Relevance –
The paper covers a range of strands of the conference; in particular Industry involvement in engineering education, Project-based learning, and Active and experiential learning

Submission Category –
Paper presentation

Keywords –
Project-based learning, Industry/academia interaction, Team-based projects, Innovative learning tools

INTRODUCTION

A number of global trends in the last few decades have changed the nature of business and trade, and in turn strongly impacted on the roles of professional engineers. The globalisation of trade, the emergence of multi-national businesses, and advances in information technology, in particular the increasing use of the internet and web-based applications, have increased competitive pressure for businesses. These developments have been causing ever-increasing cycles of technological changes, rapid developments of a broad range of new technologies, and the generation of vast amounts of new knowledge, tools and approaches that need to be understood, applied and managed by the engineering profession.

This has influenced the demands made of engineering graduates by businesses that employ professional engineers, and by professional organisations like the Accreditation Board for Engineering and Technology (ABET), the Institution of Engineers, Australia (IEAust) and the Institution of Professional Engineers, New Zealand (IPENZ). Whilst a solid understanding of engineering science principles is still a fundamental expectation of modern graduate engineers, some of the most important requirements now are the ability to communicate effectively, the ability to work independently as well as in a team, and the ability to think both critically and creatively [1, 2]. To achieve this, the ABET Criteria for Accrediting Engineering Programs require that engineering students "must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints" [3], such as manufacturability, sustainability, and environmental, economic, political, social and ethical issues. Expected learning outcomes include the ability to function on multidisciplinary teams, the ability to communicate effectively, and the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context [3]. A recent study [4] identified teamwork, communication, data analysis, and problem solving as the most important competencies that engineering graduates need to be prepared for when they enter professional practice.

The latest version of the CDIO syllabus reflects this situation by offering a framework for a "rational, complete, consistent, and generalizable set of goals for undergraduate engineering education. The syllabus defines expected outcomes in terms of learning objectives of the personal, interpersonal and system building skills necessary for modern engineering practice". In particular it states that "graduating engineers should appreciate the engineering process, be able to contribute to the development of engineering products, and do so while working in engineering organizations" [5].

The educational value of student projects involving industry has been well recognised at the University of Auckland for a considerable time. Technology management and design projects drawn from industry are organised as capstone experiences in the final year of the undergraduate curriculum.

This paper presents the course MECHENG 752 'Technology Management' as a successful case of how industry-based projects can be integrated in the curriculum to provide students with a range of open-ended, complex, multi-disciplinary problems and expose them to team-based problem solving in a realistic business, societal, and environmental context.

TECHNOLOGY MANAGEMENT COURSE

The course MECHENG 752 'Technology Management' aims to provide professional engineering graduates with the knowledge and experience required to successfully apply their professional engineering skills in today's business environments. The course design originated in the mid-1990s on the foundation of a traditionally taught Industrial Engineering course, and is centred around a Project-Based Learning (PBL) approach in conjunction with industry partner organisations. Since then, the course approach has been continually improved on the basis of feedback from students, graduates and industry partners, and in line with the evolving requirements of professional bodies and organisations such as CDIO, IPENZ and ABET. The pedagogical principles applied in the course are consistent with David Perkins' principle of 'learning for understanding' [6, 7], and with the work of Donald Schön and Chris Argyris on learning systems, learning societies and institutions, double-loop and organisational learning [8, 9].

The following course description and learning objectives are taken from the introductory page of the course website:

"MECHENG 752 is a hands-on paper offered to final year and postgraduate students. It introduces students to 'real world' problems and provides them with a solid understanding and practical experience of the innovation and technology management processes. Providing experiences that extend beyond most other University papers, the paper is an excellent chance for students who want to challenge and extend their perceptions of the environment contemporary New Zealand businesses now face.

The students work in a team based project with an industry partner. Throughout the course, they get exposed to a real-life problem, with combined technical and organisational issues of technology management. They learn how to apply systematic and strategic approaches to managing technology. Learning is supported through team work, discussions, lectures, weekly meetings with project supervisor, independent study, assignments, and written and oral presentations. As team work experience is an important skill of modern business professional, report writing, team work and project management issues are carefully moderated and monitored throughout the duration of the course." [10].

PROJECT ORGANISATION

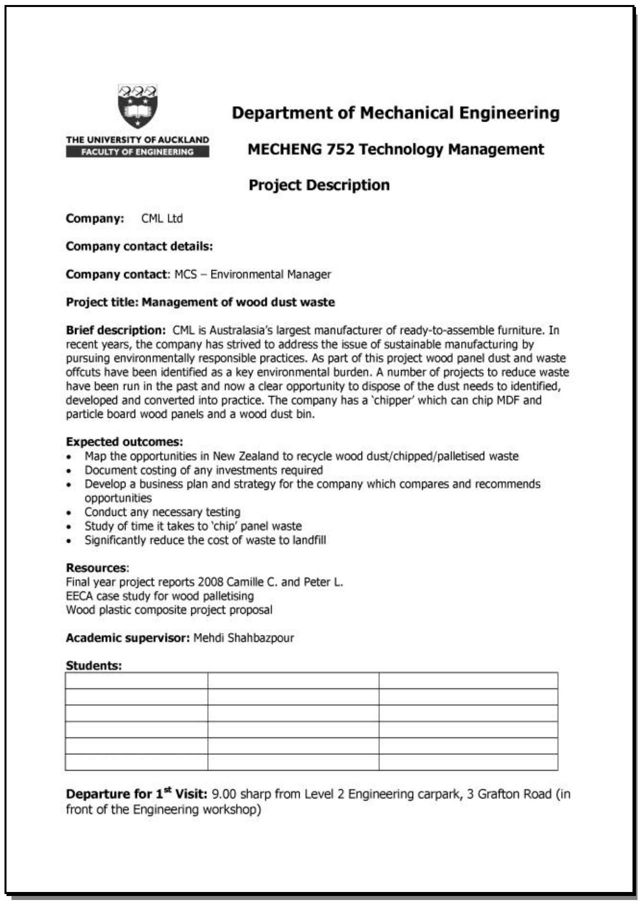
In the last few years, enrolment in the course has fluctuated between around 20 and 35 students, who are grouped into project teams of four to six students each. Team composition involves grouping of students based on their disciplinary backgrounds, academic achievements, enrolment status, learning styles, gender and ethnicity in order to generate a multidisciplinary and fair mix of teams for each project, consistent with an approach that is also used in design courses organised by the authors [2]. This provides students with a dynamic and realistic teamwork environment in line with CDIO and ABET principles, and also helps avoid 'ghettoisation' of low performing and international students with English as a second language, who generally comprise more than half of the course enrolment.

Depending on class size and number of teams, between four and six industry projects are sourced every year. They often involve industry partners who participated in projects in previous years, and sometimes even employ graduates of earlier courses. These organisations have already a good understanding of our educational objectives and project requirements, which lowers the administrative burden on the course organisers. However, each year we also arrange projects with new industry contacts, in order to benefit a wider group of companies, and to form new partnerships, which have the potential for future, more in-depth collaboration at postgraduate, research or consulting levels.

Project topics are arranged and negotiated between the course organisers and participating companies over a period of several weeks before the start of the course. This is a critical step, as the scope of each project not only has to fit the learning objectives, timescale and resources available, but also needs to be in line with the strategic objectives of the business. The aim is to create a project scenario where academic learning and practical business objectives complement each other, and where both students and industry partner are equally motivated and interested to achieve positive outcomes. If this is the case, all three parties involved – students, industry and university benefit equally from this arrangement: Students are able to observe, participate and contribute actively in real-life business processes, and thus have a learning environment and project experience which is realistic and stimulating in line with CDIO principles. Their ideas and understanding are scrutinised and refined not just from an academic perspective by their University supervisor, but also by their industry mentor in terms of business relevance and applicability. The participating business receives free input into their strategic development activities, often in areas where they lack internal resources and expertise. Through their participation in the project company mentors and staff are also included in the learning process, and have the opportunity to gain experience and develop new competencies. As students are required to apply an academically sound and proven systems approach and best practice tools, this also generates significant technology transfer opportunities for the participating business and supports its strategic activities towards improving its competitiveness. For the University the project is a prime opportunity to extend and spin-off its educational activities into industrial practice and to raise its profile in the business environment and the local community.

The following selection of project titles from the last few years gives an impression of the range of topics covered in the course:

- Waste minimisation in a food packaging process
- Optimisation of the patient service process in a hospital department
- Implementation of lean principles in a medical device manufacturing process
- Development of improvement options for the production of roof tiles
- Reduction of downtime of a continuous food production process
- Implementation of environmental management of university activities
- Management of wood dust waste in a furniture production
- ECR sample manufacturing process improvement
- CSD Factory Production Layout Implementation.


THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

Department of Mechanical Engineering

MECHENG 752 Technology Management

Project Description

Company: CML Ltd

Company contact details:

Company contact: MCS – Environmental Manager

Project title: Management of wood dust waste

Brief description: CML is Australasia's largest manufacturer of ready-to-assemble furniture. In recent years, the company has strived to address the issue of sustainable manufacturing by pursuing environmentally responsible practices. As part of this project wood panel dust and waste offcuts have been identified as a key environmental burden. A number of projects to reduce waste have been run in the past and now a clear opportunity to dispose of the dust needs to identified, developed and converted into practice. The company has a 'chipper' which can chip MDF and particle board wood panels and a wood dust bin.

Expected outcomes:
- Map the opportunities in New Zealand to recycle wood dust/chipped/palletised waste
- Document costing of any investments required
- Develop a business plan and strategy for the company which compares and recommends opportunities
- Conduct any necessary testing
- Study of time it takes to 'chip' panel waste
- Significantly reduce the cost of waste to landfill

Resources:
Final year project reports 2008 Camille C. and Peter L.
EECA case study for wood palletising
Wood plastic composite project proposal

Academic supervisor: Mehdi Shahbazpour

Students:

Departure for 1st Visit: 9.00 sharp from Level 2 Engineering carpark, 3 Grafton Road (in front of the Engineering workshop)

Figure 1. Project brief for wood waste reduction project.

Figure 1 shows an example of the project brief which is supplied to students at the start of the course. As can be seen from the Expected Outcomes, students are required to consider a broad range of issues in a meaningful business context. In order to achieve their project objectives, they not only need to apply traditional engineering analysis, but do this from a broad systems perspective which includes societal, environmental, and financial aspects. Whereas the technical content is different for every topic, this systems view is common to all projects. Also common is the requirement of a thorough problem analysis, which generally includes a stakeholder analysis and the evaluation of the state of art in the respective project area, and the consideration of a wide range of options to develop the required project outcomes.

TEACHING

This course has been designed and structured to deliver effective Project Based Learning (PBL). This has evolved over a period of more than 15 years in a range of design, industrial engineering and engineering management courses (see e.g. [11]). The course is presented in ways which encourage the students to generate, learn, and apply new knowledge in a meaningful, realistic context. This is achieved by carefully integrating the teaching elements of the course with the requirements of each phase of the project. This is critical since the students are learning the required theoretical knowledge and systematic tools that they can apply to their project, while working on the project with the host company. Table 1 illustrates the alignment of the weekly lecture schedule with the project phases that apply to a typical technology management project.

Table 1. Integrating lectures with the project.

Project Phase	Lecture Topics
Initiation: students are just becoming familiar with this type of industry-based project, formed into new teams and becoming familiar with the specific industrial problem that is the focus of their project.	• Introduction to technology management • Effective team and project management • Drivers of technology and innovation • Strategic and systematic innovation
Analysis: students are fully engaged with the host company, and need to systematically analyse and make sense of the company's requirements, their own observations and the technical and contextual information they are provided before formulating solutions.	• Diffusion of technology and innovation • Systematic and strategic analysis tools • Process improvement tools and methods • Trade-off management • Change management
Development: students are working on a number of solutions and means of deciding on the best option to propose to the host company.	• Economic decision making • Quality management and associated tools • H&S management and associated tools • Sustainability and associated tools • Knowledge management and associated tools

Another important aspect of the teaching is the instructional approach. Perkins' learning principles of 'bridging and hugging' [12] are adopted in the course, which require teaching staff to act primarily as mentors rather than just teachers, with the aim of helping students connect, extend and apply their knowledge, ideas and skills to the solution of their project tasks. Additionally the teaching staff encourage learning across subject matters and disciplinary boundaries in order to achieve a holistic project outcome from a broad range of perspectives (see above).

In order to generate this type of learning environment, students are provided with an elaborate, but implicit, project and teamwork framework which helps them achieve the required outcomes. At the same time this framework acts as a template of sound project and team management principles for their future professional practice. In our experience from a range of PBL-based courses, the development of students' teamwork ability is a complex, challenging and sometimes traumatic process and experience for them, and therefore needs to be carefully organised and monitored [2]. Important aspects which need to be addressed are team composition and team building, roles and responsibilities within the team, communication and information sharing, fair distribution of teamwork including the prevention of free-loading, and the resolution of conflicts and disagreements. Another important teamwork issue is the prevention of the segregation of project tasks into specialist topics within the team, which often happens when some students have existing specialist knowledge or skills, have a strong preference for one particular type of work, or want to avoid specific work areas [2].

As in our other PBL-based courses and design projects, we provide information, rules and guidelines for best practices of project management, teamwork and time management at the start of the Technology Management course [13]. Teamwork support includes weekly meetings with project supervisor, sample 'ground rules' for internal team processes, a written 'teamwork contract' that each student team has to negotiate between its members, teambuilding exercises, a peer assessment process at the end of the course, and team-based assessments which will be discussed in the following sections.

ASSESSMENT

The assessment schedule has also been carefully designed to achieve student engagement with the lectures as well as the team project, while providing students with regular feedback from the teaching staff as well as the industry partner. It comprises of the following elements:

- Weekly Insights 18% (9x2%)
- Team Progress Blog 12% (2x6%)
- Project Proposal 10%
- Interim Report 15%
- Final Report and Presentation 25%
- Reflections on Team Work 5%
- Reflections on the Course 15%

Weekly Insights and Team Project Blog are assessment and learning tools which have been introduced to designed to motivate students to actively participate in the lectures and project activities, and help them process and internalise new knowledge and information as it is generated. Although each of the individual insights or blog submissions is quite small and accounts only for a small number of marks, they are very effective in terms of active and closed-loop learning, which has also been proven in our other PBL courses (see e.g. [2]). Like the other assessment elements in the Technology Management course, the blogs and weekly insights have to be submitted online through the course website (Figure 2). This format and procedure has been chosen as many of the ‘Web 2.0 generation’ of students are familiar and comfortable with this concept, and as it fits well with the other communication and feedback features of the course website.

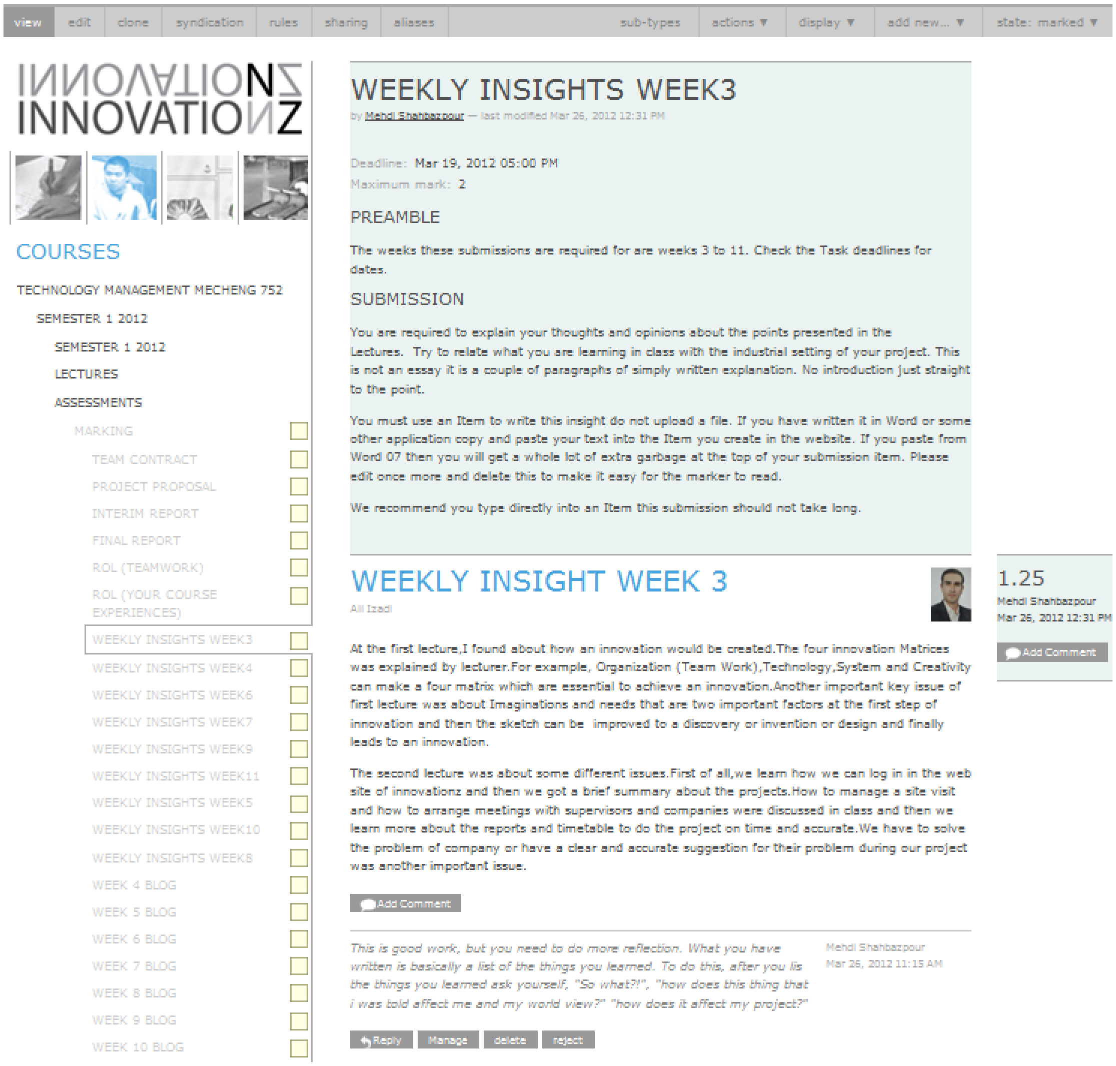


Figure 2. Web 2.0 style website used for assessment.

While project management is only covered in one formal presentation at the start of the course, the coursework and assessment structure act as an implicit framework to foster sound project management practices. Like the experiential learning process applied for the technical aspects of the project, this approach encourages students to pick up good practices by actively doing their project work, practising ‘learning by doing’.

Project Proposal, Interim Report and Final Report assess the progress and perceived levels of achievement the different project teams have made in each of the phases of the project, as demonstrated by their online submissions and oral presentations. These marking components, which collectively account for 50% of the final course marks, assess tangible project achievements and progress made by each of the teams. As there is a significant learning curve involved for the students to adjust to the complex project requirements, the weighting increases gradually. In order to foster teamwork and team-based development, marks are generally assigned to the team as a whole, but a number of factors and indicators, such as the outcomes of the confidential peer assessment scheme at the end of the course, and the statements made in the Reflections on Teamwork reports, can be used to moderate the marks of individual students if deemed necessary.

Reflection on Teamwork is a particularly effective tool to identify and remedy negative factors and habits which affect teamwork. Students are asked to reflect on the experiences they have had with teamwork, on the interactions between individual team members and on team dynamics and submit this on the course website about half way through their project. They must consider their own perspective and expectations and those of other team members, and describe their opinion on teams at the beginning of the course and at the time of submission. The report is expected to be an open and honest account of each student's thoughts, and should explain the value they have drawn from their experiences involving teamwork which they consider most significant. From our observations and from the feedback in the submitted reports, students find this assignment a very useful way of reminding themselves of sound teamwork habits, and many use their insights to bring their team process back on track.

Reflections on Teamwork and Reflections on the Course produce particularly beneficial learning outcomes. These components together account for 20% of the course marks, and require students to consider all issues related to their teamwork, learning process and professional roles. The report requirements encourage students to reflect deeply on their activities and roles during their project development, within their team and in other course activities, and ask them to question their existing behavioural patterns, attitudes, and objectives. The submitted reports are generally of a very high standard, and reveal deep insights and a high degree of reflective learning during their composition. Apart from their very beneficial impacts on students' learning, these tools have also provided excellent, in-depth feedback to the course team on all aspects of innovation and technology management and project-based learning, which has significantly benefitted the evolution and refinement of our educational approach.

CONCLUSIONS

The effectiveness of our educational methods and tools has been continuously monitored and optimised since the instigation of our PBL approach in 1995. In particular the information we received from the students' course reflections over the years has helped us develop a good understanding of what elements of our PBL were most effective in achieving the course learning outcomes and the requirements of the profession as for example formulated by ABET and CDIO. Further insights were developed from a research study of students focussing on their experiences gained in our project and team based courses in terms of learning objectives, implementation procedures, assessment criteria and expected outcomes [11], from many discussions with our industry partners and from communications with other industry professionals and academics associated with organisations such as CDIO, IPENZ, AAEE and ASEE.

In general, all of the feedback received on the course outcomes has been very encouraging. In particular the response of our industry partners has been very positive, as indicated by the number of graduates from our courses who have been given job offers by their former host companies. The feedback of former students also highlights the specific educational benefits of our PBL approach. Below are typical responses received in the last few years, which demonstrate the alignment of the Technology Management course with the requirements of the CDIO syllabus:

- Technology Management to me was a very exciting and helpful project which gave me an insight to a real world of engineering at work.
- The learning in this course was mostly done practically. While text book learning is fine for in classrooms, nothing beats hands on experience.
- This project has taught me a lot of skills that I won't be able to obtain from any other subjects.
- Throughout this project I was able to see the bigger picture of where the company was going and how they were planning on getting there, even with outside interferences (The Economy) changing the way they need to do things. It has been eye opening to actually get inside a company and see in-depth in how they work and go about solving problems.
- This course served us as a reminder of the many facets of responsibilities an engineer is expected to shoulder in industry. From the technology management course, I learnt that in practice, an engineer's role goes beyond numerical procedures involved in product design, manufacture, maintenance, etc. From an engineering student's point of view, this course taught me that detailed number crunching alone does not make an innovation successful; there is a large array of other parameters to be observed from industrial practices and trends.
- The project was an eye opener for me. It was the first time that I undertook a project related to the industry. Working together with the representative from the company was a good learning experience. It taught me how to deal with the working society at the right manner. Apart from that, I was also exposed to the real world of manufacturing systems.
- If one were to ask me now what I learnt from this project, I wouldn't be able to give a short answer. I learnt to swim in the deep end, more so than in any other previous project. I learnt to create bounds and limits from an initially vague set of objectives. I learnt to work full-on in a relatively large project team – the largest so far in my years in engineering. Perhaps most importantly, I gained a taste of what it's like to do a project in industry. And I like it.

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